Towards a fuel poverty definition for Spain

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Abstract: *During the last years, an increasing interest has been developed so as to address the problem of fuel poverty which is already affecting a huge number of European citizens. In 2013, the European Parliament has claimed to the Commission and State Members through several resolutions, the legislative development of policies in order to tackle energy vulnerability of households. In 2000 the UK Government, through the Warm Homes and Energy Conservation Act, established that a person could be regarded as fuel poor if he is a member of a household that cannot get warmth at a reasonable cost.*

Nevertheless, in order to establish the incidence of fuel poverty among Spanish households, it must be understood which should be the adequate thresholds for indoor temperatures. The research here presented proposes new indoor temperature thresholds for fuel poor households based on adaptive comfort models.

Keywords, Fuel poverty, adaptive comfort, low income households, Spain, comfort gap

Introduction

The present research falls within European interests on fighting poverty through the development of an inclusive economy with a strong emphasis on job creation and poverty reduction (1). Furthermore, recent UE documents encourage the State Members to develop their own methodologies in order to quantify fuel poor households (2), propose the creation of an European Fuel Poverty Observatory or even the establishment of housing energy retrofitting actions as a priority in energy efficiency EU programmes (3).

Within this context, the present research attempts to push forward the establishment of a definition of fuel poverty for Spanish households through the delimitation of the adequate indoor temperatures. This paper presents first results of the implementation of the proposed method in a building block.

Fuel poverty and indoor thermal comfort

Fuel poverty has been defined as 'the inability to afford adequate warmth in the home'. It can be appraised in households through the Fuel Poverty Index in which the three factors that cause it are reflected: housing lack of energy efficiency, high energy bills and low household income.

$$Fuel\ Poverty\ Index = \frac{energy\ consumption\ x\ energy\ price}{income}$$

In that equation, the most difficult factor to measure is the energy consumption of dwellings which includes besides heating costs, domestic hot water, lighting, equipment and cooking. United Kingdom methodology sets the adequate level of warmth in 21ºC for living rooms and 18ºC for the rest of the rooms (4). These temperature thresholds are based on recommendations done by the World Health Organization (5) due to health risks derived from living in cold homes.

However in order to develop a fuel poverty definition for Spain, it must be doubted the suitability of these temperature thresholds for Spanish householders. On one hand, there has been scientific evidence of diseases and mortality rates related to high temperatures for years (6), a strong relation which was definitely highlighted by the heat wave of 2003. Thus, cooling needs must be included in the delimitation of the *adequate temperatures.* On the other hand, it is well known that the temperature at which mortality increases, differs from one population to another due to the adaptation of people to the weather they live (7). Hence, this supports that the adequate indoor temperatures must be adapted to the Spanish weather conditions.

Besides that, given the poor energy performance condition of low income households added to the lack of heating or cooling systems (8), as it can be seen in Figure 1, makes the adequate temperatures unaffordable for them. This means these households are likely to suffer from extreme hot and cold temperatures which make it urgent to develop a methodology so as to evaluate their indoor thermal conditions.

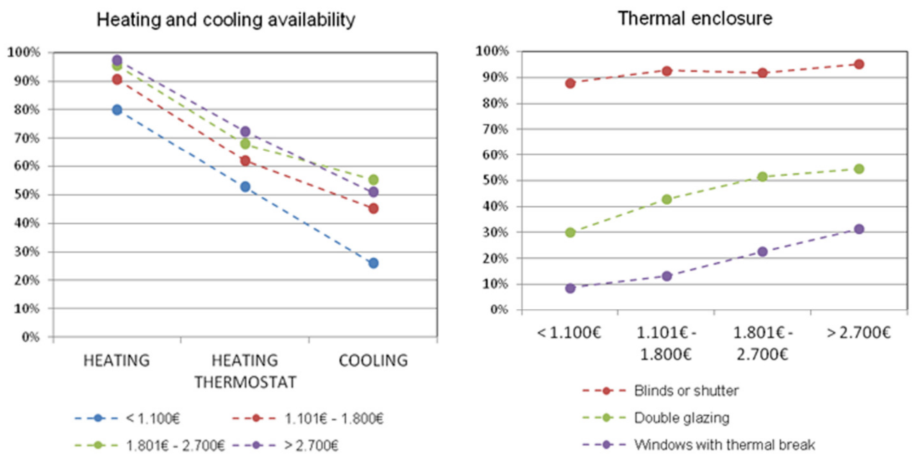

Figure 1 Left: Heating and cooling availability of households in the Autonomous Region of Madrid according to their monthly income level. Right. Energy efficiency measures in households in the Autonomous Region of Madrid according to their monthly income level. Source: Sanz,A., Sánchez-Guevara, C. et al. 2014.

Nowadays, the evaluation of indoor thermal conditions in buildings has evolved from static models developed by Fanger and gathered in the ISO 7730 (9) to a dynamic approach based on adaptive models: the one gathered in CEN 15251 (10) developed by Humphreys and Nicols and the other one collected in the ASHRAE 55-2010 (11) carried out by de Dear.

Adaptive comfort model is based on field research and establishes the dependency of occupants' thermal comfort of the external temperature. The ASHRAE model, based on an extensive field work conducted in numerous countries around the world, sets the operative comfort temperature (T_{ot}) as follows:

$$T_{ot} = 0.31T_o + 17.8$$

Where T_o is the mean external temperature of previous days (between 7 and 30 days). Furthermore, the model establishes two comfort zones; the first one, for the 90% of acceptability ($T_{ot} \pm 3.5^0C$) and the second one for the 80% of acceptability ($T_{ot} \pm 2.5^0C$).

Materials and methods

a) The case study is a linear building block from the neighbourhood of San Cristóbal de los Ángeles. It is located in Madrid, whose climate is classified as a D3 according to the Código Técnico de la Edificación.

This neighbourhood was identified as a vulnerable neighbourhood (12) and the indicators that made it vulnerable were a 25.5% of illiterate or with no studies population, 1.5% of houses with no toilet and an unemployment rate of 20.89%. According to that report, the majority of the population living in these neighbourhoods are sheltered in dwellings built between 1960 and 1975.

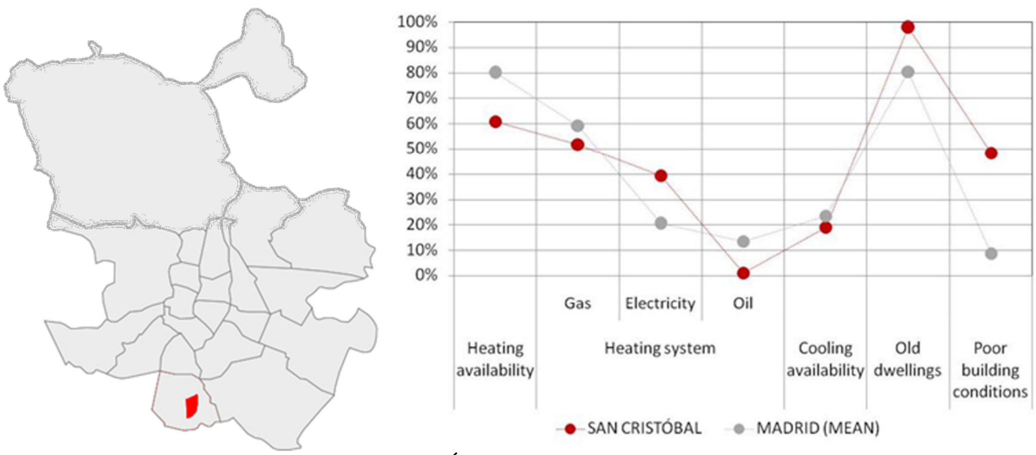

Figure 2 Left: location of San Cristóbal de los Ángeles in the city of Madrid. Right: dwelling characteristics comparison between San Cristóbal and Madrid mean values. Source: personal compilation from 2001 Census data.

Detailed data from 2001 census, plotted in Figure 2, shows some shortfalls in the neighbourhood housing stock compared to the mean values of Madrid, in line with what was pointed out in Figure 1. As it was expected, this neighbourhood, with a low socioeconomic level, suffers from some building deficiencies as well, such as lack of heating and cooling systems, the dependency of energy sources such as electricity with likely increasing prices, an old housing stock mainly built before first energy efficiency regulations (CT-79) and in bad conditions.

Figure 3 shows the neighbourhood floor plan, formed by the most common dwelling typologies of this period: linear and H shaped building blocks. For this research advance a type of linear block is presented. The single block consists of five floors with two flats for each staircase and it forms larger blocks through the addition of blocks. Figure 3 shows floor, facade and section plans and Table 1 presents the envelope thermal characteristics.

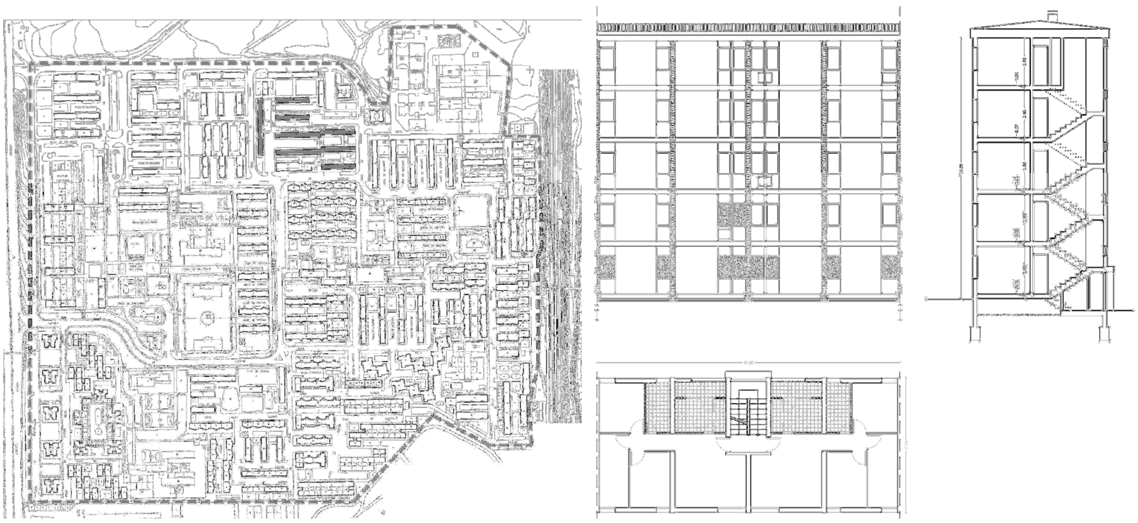

Figure 3 Left: Neighbour floor plan with the analysed block in black. Right: Floor, main facade and section of the studied building block.

Table 1. Building envelope thermal characteristics

Envelope	External walls	Roof	Floors	Windows (glass)	Windows (frame)
U value (W/m^{2}K)	2,76	2,36	2,28	6.12	5,26

b) Dynamic thermal simulation was performed in the Energy Plus 7.0 modelling software. Each dwelling was divided into two thermal zones, rooms and daily living spaces, in order to achieve a better appraising of indoor thermal comfort. Internal gains values regarding occupants, equipments and lighting were set like those used in energy labelling software (Herramienta unificada LIDER-CALENER). The model was evaluated in a free running mode and natural ventilation through windows was set during night summer time. Besides that, the most representative dwellings within a north-south and east-west oriented blocks were appraised.

c) Indoor comfort temperatures were set through the adaptive comfort model gathered in ASHRAE 55-2010 for naturally conditioned spaces. The mean outdoor air temperature was set as the mean value of the last 7 days temperature. Both comfort temperature thresholds were studied: the 80% of acceptability for general householders and the 90% for those regarded as more vulnerable such as children, elderly and sick people. Figure 4 shows the comfort thresholds developed for de weather of Madrid.

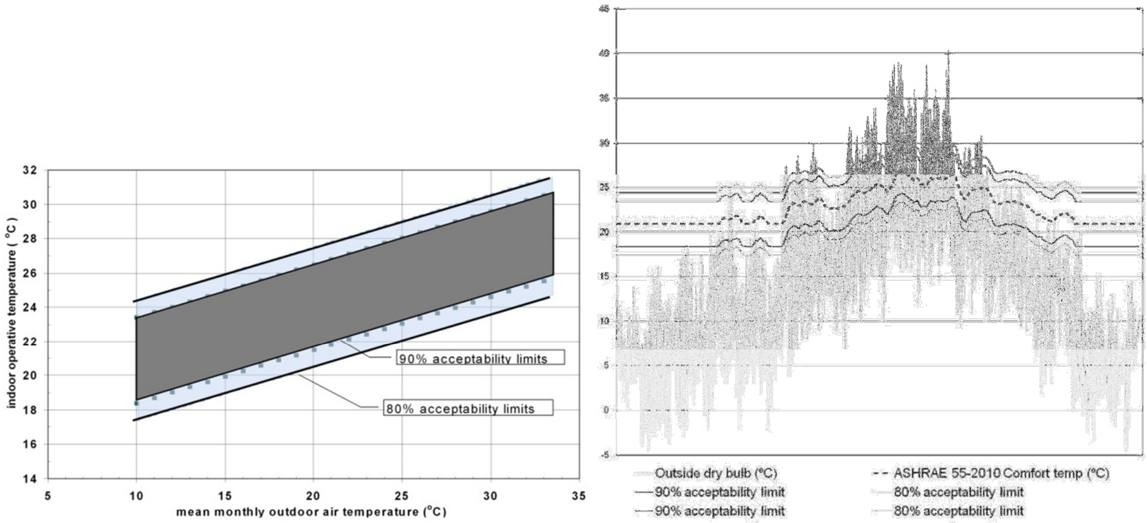

Figure 4 Left: Acceptable operative temperature ranges for naturally conditioned spaces (11). Right: Comfort thresholds for Madrid weather calculated according to ASHRAE 55-2010 adaptive comfort model.

Results

Room and living space indoor temperature results were compared against calculated comfort temperatures as it can be observed in Figure 5. For the coldest period, where the mean weekly outdoor temperature was lower than 10ºC, comfort temperatures were considered constant and minimum values.

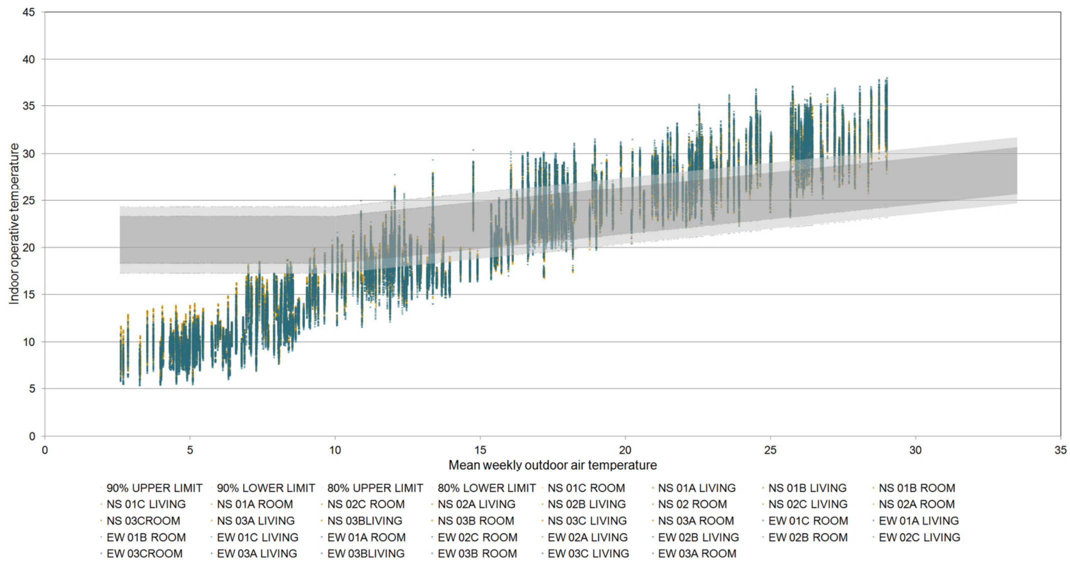

Figure 5 Dwelling indoor temperatures along with calculated comfort temperatures.

In order to get an accurate appraising of indoor thermal comfort conditions, the degree hour criteria gathered in EN 15251 was utilized. This method takes into account not only the number of occupied hours that are out of the comfort range but the degree of discomfort which is measured with the difference between the actual temperature and the comfort threshold. This is what authors have defined as the *comfort gap.*

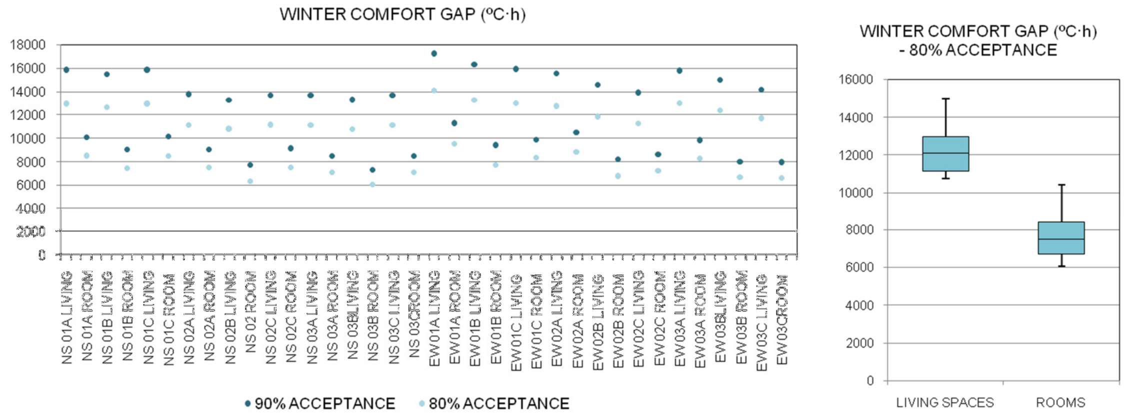

Figure 6 Left: Winter comfort gap in studied dwellings according to degree day criteria (ºC·h). Right: Winter comfort gap rages for all analysed living spaces and rooms.

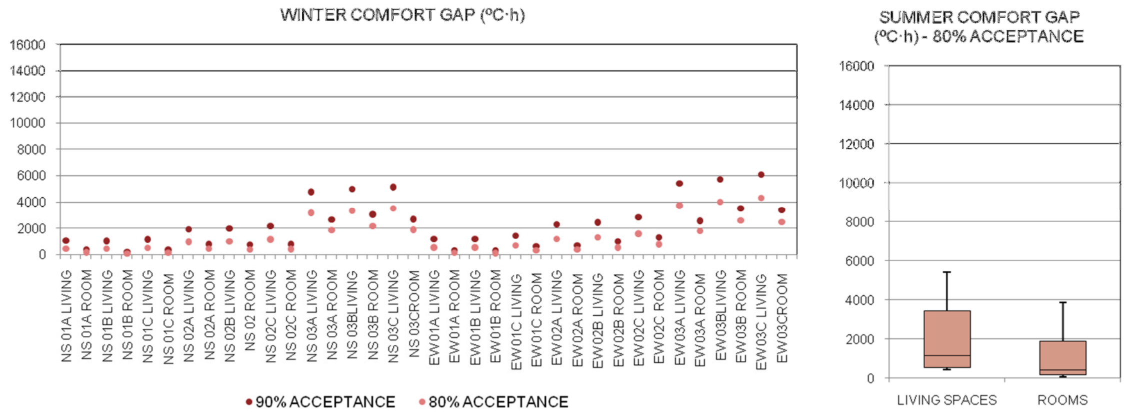

Figure 7 Left: Summer comfort gap in studied dwellings according to degree day criteria (ºC·h). Right: Summer comfort gap rages for all analysed living spaces and rooms.

As it can be regarded in figure 6, dwellings with worse winter thermal performance are those located in ground and upper floors and in the edges of blocks due to a larger exposed surface. The position within the urban morphology poses a weaker position regarding winter temperatures with a higher comfort gap in dwellings with east-west facades. Regarding summer temperatures, an east-west orientation and a border location within the block poses a worse summer performance in dwellings. By contrast, while upper floors suffer from the highest temperatures, ground floors enjoy the lowest summer comfort gaps as it can be derived from figure 7. Furthermore, figure 6 and 7 show that living spaces are those that registered highest comfort gaps, which can be explained due to longer occupancy hours. Nevertheless it must be highlighted a non negligible difference in thermal performance among different dwellings. These results go in line with previous research (13) which demonstrated the influence that the urban position of dwellings have upon their energy performance.

Conclusions

The *comfort gap* is found to be a useful tool in order to measure whether householders may be living under inadequate temperatures as well as the distance of these temperatures from comfort. Thus, this method allows the identification of those households more in need. Finally, given the studied case it can be stated that he poor thermal performance of these kind of constructions do not allow householders to live under adequate temperatures and that they can be considered as cold homes with summer overheating problems which reinforce the initial idea of the urgent inclusion of cooling needs in Spanish definition for fuel poverty.

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